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Science and the Air Forces

(A lecture [redacted] given to students at the Air University, Air Command and Staff School, Maxwell Field, Alabama)

January 10, 1947.

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Introduction

The mission of the Air Forces in time of peace is to establish the air power deemed necessary for our national security. The revolutionary developments of the last war, in particular, radar, rocket-propelled missiles and atomic bombs have focused attention on the role of modern science as a factor in air power. Hence it is appropriate that you as future leaders in the Air Forces should try to understand what science is and how it operates and that you should be brought into contact with current ideas about the principles and practices which must be followed to secure the help of the scientific resources of the nation in doing your job.

This lecture attempts to give you some general information about the path from discoveries in pure science to new weapons; the broader role of science as a method of attacking all of your problems, and the responsibility of the Air Forces in promoting science itself. We shall then discuss the goals, principles, difficulties, and necessary courses of action to insure cooperation in scientific matters between research agencies and the Air Forces and between industry and the Air Forces. Following this, we will examine the methods available for developing an atmosphere favorable to the support and use of science within the Air Forces itself at the command, staff, and operating levels.

Science and the Development of New Weapons

A familiar method in which science may operate to assist the Air Forces is that of contributing to the development of new or improved weapons, i.e. specific items of military equipment. Any such weapon usually has a long and complicated pedigree. A large number of persons are involved in its development and it springs from many apparently unrelated scientific discoveries of the past. To ask what individual invented it has as much meaning and no more as to ask who is your ancestor. Each generation you go back multiplies the number. While inventive ability is still of great importance, the individual inventor plays a small role in most developments today. The striking advances in the last war came from the mobilization of a large number of people with a variety of skills directing their efforts toward a common task, i.e. from such groups as the Peenemunde group, or the Radiation Laboratory.

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Any development of a specific weapon involves a large number of steps, some of which may be omitted in special cases. We may label the steps as follows: pure science, applied science, development, laboratory tests, service tests, production, training, tactical evaluation, service use. The steps are interrelated and can not always be separated. The virtue of the well organized attack is that continuous contact is maintained between groups responsible for the various steps.

Perhaps a concrete illustration will be helpful in understanding these steps. Let us consider the radio proximity fuze. As most of you know it is a small transmitting radio station with a receiver to detect any reflections of the transmitted wave. It is used to explode a projectile on close approach to an air target or to the ground. Some of the investigations in pure science without which this development would have been impossible are those relating to radio wave propagation; emission of ions from hot filaments; conduction of electricity in gases at low pressure; electrical circuits producing electrical oscillations; magnetic materials (alnico); conduction of electricity through crystals; chemistry of plastics. In the development it was necessary to do some fundamental scientific studies of radio reflections from aircraft and of radiation patterns from antennas.

Some of the past developments in the field of applied science on which the development of the radio proximity fuze was dependent are electrical generators, rectifiers, filters, amplifier tubes, the thyratron tube, plastics, electrical insulating materials with good properties at high frequencies.

Some of the development problems for this application were small rugged tubes to withstand vibration and shock; small generators rotating at very high speeds with little vibration; stable electrical circuits permitting large tolerances on accuracy of components; insulating materials of improved mechanical properties, rugged resistors and condensers.

The other steps are more familiar. A great variety of laboratory tests were devised and components and complete fuzes were tested. Service tests were made at proving grounds. The fuzes were placed in production, and production quality control tests developed. Military personnel were trained in the inspection, handling and use. Tactical evaluation tests were made by military agencies and the fuzes were finally used against the enemy.

Beginning with the third step, the development stage, all of the remaining steps were accomplished between December 1940 and August 1943. For strategic reasons service use was delayed more than a year. During the whole period of development there was a continuous interchange of information and reaction from the results obtained at any stage on the preceding with consequent speeding of development. However as one gets back to the applied science and pure science stages the effect of the reactions from the final stages diminishes. It is important to realize that this results from the fundamental fact that each step can draw upon all existing knowledge available at the preceding level and also stimulate the preceding level to advance by further exploitation of the one before until the pure science level is reached. Here we are in contact with the unknown and the mere existence of some practical goal is of no help. The discovery of radio waves was not made by Hertz because of any practical task such as a proximity fuze or even the goal of long distance communication. Röentgen's discovery of X-rays was not stimulated by any desire to see through solid objects.

There are strong interactions between pure and applied science as applied science develops better tools to explore the unknown. Likewise applied science applies all of the techniques of pure science to exploit in detail major fields of knowledge and to make advances. But if scientists understand their own subject correctly, the setting of such a task as guiding a missile at 3000 mile range will not help much in making an advance in pure science to aid the solution. If an early solution is required, applied science and engineering development groups must solve the problem as best they can with available tools.

The United States has been outstanding and has rapidly taken the leadership in applied science but has definitely contributed less than its due proportion to pure science, largely because our national characteristics are such as to emphasize immediately useful practical goals and to be less interested in projects which promise material benefits only at some future date. Today's applied science rests on the pure science of the preceding generation, knowledge of which is taken for granted. Just as replacing our forests or the fertility of the soil seems to have less attraction to our American mind than the rapid exploitation of presently available resources, so the support of pure science is less popular than the application and exploitation of scientific knowledge currently available.

The present military system of establishing requirements based on service needs is effective in the development of new weapons, provided the requirements are consistent with the state of development of pure science. To make significant progress pure science itself must be supported in its efforts to advance fundamental knowledge without the limitation of too specific practical goals. Many authorities have called attention to the fact the applications of pure science have practically caught up with the knowledge available.

The Broader Role of Science

The last war not only demonstrated the great power of science, especially when scientists were organized into groups incorporating specialists in a large number of fields, in developing new and effective weapons but also saw the birth of a much broader application of science to military problems. This broader application arose from a consideration of military problems and objectives in the most general manner, stating them in terms of overall tasks to be accomplished rather than in terms of the component steps calling for specific weapons. In this application science was not restricted to applying physics and chemistry to produce gadgets, but the scientific method of procedure was applied to tactical and strategic problems. This work was pioneered by the operational analysis groups attached to the staff of most of the field commanders.

An example of this broader application of science that might well be studied in detail by the student is the investigation of the most efficient B-29 formations carried out by the Army Air Forces and the National Defense Research Committee. The problems were formulated in such general terms as "In what way, how frequently, and how effectively can fighter planes attack a single B-29 airplane? A squadron of B-29's with standard stacking?"

The scientific procedure involves such features as objective and quantitative analysis, objective observation of data, use of experimental method where possible, control and study of effects of variables one at a time where possible, and willingness to use all available techniques and sources of expert knowledge. These procedures can be applied to practically any type of problem with profitable results, and this fact was being discovered again and again by military leaders towards the end of the last war.

In terms of such broad problems, the mission of the Air Forces has been analyzed from the technical point of view by Dr. Th von Karman, chairman of the AAF Scientific Advisory Board, as follows:

(a) To move swiftly and transport loads through the air
(b) To locate targets and recognize them
(c) To hit targets accurately
(d) To cause destruction
(e) To function independently of weather and darkness
(f) To defeat enemy interference
(g) To perfect communications
(h) To defend home territory

Air power is directly proportional to the effectiveness with which these tasks can be accomplished by the equipment and personnel at hand or available in a very short time. It is the broader role of science to inquire as to the most effective solution of these tasks, to suggest lines of development of the most suitable types of equipment, to aid in such developments, to devise methods of test, and to evaluate performance from the standpoint of the broad task to be accomplished.

The Responsibility of the Air Forces

Every citizen and every group of citizens including those from science and industry has an inescapable responsibility for national defense and the security of the nation. To the Air Forces, however, is entrusted the final responsibility for insuring that the nation is prepared to wage victorious air warfare offensively and defensively if attacked. This responsibility can not be delegated to any other agency, yet the Air Forces would be unwise to rely solely on its own resources in the fulfillment of their responsibility. The Air Forces should call on all available talent and facilities in the nation and should sponsor the creative work of scientists and engineers so necessary to the creation of national strength. The tasks set should include broad as well as specific assignments and long-range as well as short-term tasks.

The Air Forces must assume leadership in securing the cooperation of science and industry. All three groups must arrive at an understanding of the principles, goals, difficulties and necessary actions by each group to fulfill their separate responsibilities for national security. The problem of securing this cooperation during peace time is a very difficult one and positive steps must be taken by all those concerned.

In addition to the utilization of scientific and industrial organizations and of technical skills and abilities wherever found, the Air Forces have definite responsibilities for improving their own utilization of science and scientific methods. Personnel at all levels must include many more scientifically qualified men and all personnel must have greater knowledge of the methods and possible accomplishments of science. More effective use must be made of the technical skills of men already in the Air Forces family and of the AAF scientific and technical facilities. The Air Forces must recruit and train qualified personnel for their own scientific work.

Cooperation between Science and the Air Forces

Goal.- The goal of the cooperation between science and the Air Forces has been stated in many ways, for example by Colonel Glantzberg, "to build that effective partnership which will maintain for the United States that technical superiority in the air needed to insure victory in any future war". In order to emphasize that this is a mutual goal we may restate it in terms of results to be accomplished within each group, namely, to create within the Air Forces a scientific atmosphere and to develop a continuing interest on the part of leading scientists in the problems of air warfare. If these goals are reached, technical superiority will be attained.

The creation of a scientific atmosphere within the Air Forces implies not only the building of an organization in which the scientific method and procedure is applied in the broadest possible way but still more the development of an esprit de corps favorable to these methods and procedures. There must be not only a willingness but a desire to use objective and quantitative procedures where possible, to rely, in technical matters especially, on those with expert knowledge, and to look for technical leadership to technically qualified leaders.

The interest of leading scientists in the problems of air warfare is of course greatly affected by the scientific stature of the Air Forces. However leading scientists should be interested in the scientific stature of the Air Forces as well as in other scientific problems of the Air Forces. The goal is here stated as one for the scientists who have now come to realize the necessity of coming to grips with problems arising from the impact of science on society.

Principles. - Cooperation between science and the Air Forces should be based on certain principles which are now well known. These are as follows:

1. An adequate national program for extending the frontiers of knowledge in various fields of science is a necessary adjunct to the maintenance of the military security of the nation.

> Previous experience has shown that every scientific development eventually finds its way into activities connected with warfare. Modern war is increasingly total warfare and utilizes all the resources of the nations involved. Fundamental or basic research which is here under consideration requires time. Whereas applied research and development can be expedited by the application of more money and manpower, fundamental research contains many unpredictable elements and uncontrollable factors. Wars are fought with weapons based on fundamentals discovered during the preceding years of peace. It is therefor clear that military authorities should foster fundamental as well as applied scientific research.

2. Fundamental scientific research is dependent on an atmosphere of freedom from immediate specific goals and time tables, freedom to discuss and exchange ideas, and freedom from controls and restrictions.

> The discovery of new knowledge is an intellectual activity of the highest type and flourishes only in the atmosphere of greatest freedom. We shall see that many of the difficulties of cooperation arise from the implications of this principle and its apparent conflict with military practices.

3. The results of fundamental research are applicable in non-military as well as military fields, and furnish the broad base from which all applied research and industrial developments proceed.

> This principle has many implications. Whereas, as previously stated, the military authorities should foster fundamental research, they should in no way dictate or control the use of the results. The Air Forces should maintain close liaison to keep informed on developments with immediate military applications. It is appropriate that some of the cost of fundamental research but not the whole cost be charged to military preparedness.

4. As scientific developments proceed from the stage of pure research to applied research and to development, free enterprise and initiative should be maintained and centralized dictatorial control of projects, funds, and facilities, should be avoided.

> Ideas and skills are widely dispersed. Even though the goals of applied research and development projects are concrete and specific, the attack on these goals should be diversified. Freedom of the agencies and scientists engaged in the work is a necessity here as in fundamental research if the best use is to be made of their abilities.

<u>Difficulties</u>. - It is well to face frankly some of the difficulties which have arisen or which may arise in cooperation between science and the Air Forces. Perhaps the foremost is that of the apparent conflict between scientific freedom and military security. The point of view of the scientist has been ably presented by L. N. Ridenour in an article in the November 1945 issue of Fortune. There is no disagreement on the desirability of secrecy in peace-time on the details of the design and performance of military weapons, procurement statistics, tactical and strategical plans, and similar matters. The

scientist feels, however, that any attempt at secrecy on basic scientific matters is actually detrimental to national security. In the first place it is ineffective, because the phenomena of nature are universal and can not be kept hidden; and in the second place secrecy handicaps the exchange and interplay of discussion between scientists which accelerates progress. The scientist feels that the best guarantee of security is the maintenance of technical leadership.

Secrecy regulations also introduce difficulties in acquainting civilian groups with the status of Air Forces technical problems. These regulations are sometimes misused to conceal incompetence, to secure political advantage, and to indirectly control the release of scientific information by civilian groups. These abuses must of course be corrected.

A second difficulty arises from the very different method required to successfully conduct fundamental research as compared with that required on an applied research or development project. Development projects can be definitely scheduled, their cost and time estimates can be made, and their rate of progress can be to a large extent controlled by varying the amount of financial support. So long as they involve no new fundamental scientific knowledge, a successful result can be practically guaranteed if sufficient funds and qualified personnel are available. In fundamental research on the other hand the outcome of any specific project can not be guaranteed to be that desired. The estimates of cost and time are almost always found to be illusory.

For example, once the small nuclear energy pile at Chicago showed the possibility of a chain reaction, the development of the atomic bomb was only a matter of money and effort. It was a development project and other nations can be expected also to complete a similar or better development by the expenditure of money and effort. Likewise the development of nuclear power plants is a development project. On the other hand the development of a cure for cancer or of an accurate long range missile is not a development project. The fundamental scientific knowledge of the cause of cancer, and the factors controlling cell growth are not yet available. Similarly the basic knowledge required in the long range missile problem is not at hand. While it is probable that the expenditure of time and money will accelerate the solution of such problems, it is not certain. The necessary advance may come from some obscure worker and perhaps from some one not even working on these particular problems at all.

The results of a development project are physical; those of fundamental research mental and intangible. Any liaison officer can see progress in pieces of equipment completed, or even drawings or reports in progress. Progress in fundamental research is erratic and may even be backward for a time. It can not be measured by the volume of a report or by man hours expended. The scientist himself can not foresee the possible applications of his results or evaluate their true worth. Many of the difficulties between scientists and military men arise from confusion between research work and development work and the attempt to accomplish by the development procedure a job which requires fundamental research rather than applied research. For example, guided missile development requires fundamental research. It is not known whether an anti-V2 missile can be made to work or not. There is little prospect of success in solving this problem by a one-year development project.

A third source of difficulty lies in the differences in temperament between scientists and military men. Scientists are led; military men are commanded. Scientists have only the authority of personal competence; military men have the authority established by their rank. An ideal scientific organization consists of an association of small groups with each member free to make suggestions to be considered on their merits and led by men whose technical accomplishments command respect and emulation. A military organization has a chain of command and each man is trained to obey the orders of his superior officer regardless of his personal judgment. Officers are trained to make quick decisions. This training and temperament so necessary on the battlefield is entirely unsuited to scientific work. I have purposely painted the characteristic temperaments in sharp contrast, knowing that the ideal military officer leads rather than orders and that discipline is necessary even in a scientific organization. However all of you should be familiar with the fact that scientific people are antagonized by too much command.

A fourth source of difficulty arises from the different concepts of allocation of credit for ideas and work and the handling of publicity and public relations in general. In most scientific organizations with a few exceptions emphasis is placed on the personal contributions of the individual. In a military organization as well as in many industrial organizations the individual is subordinated to the group. Team work is stressed; there may be individual recognition of individuals within the group but it is the work of the whole team which is emphasized in public relations. The scientist aims to give references in his reports and publications to other individual workers and emphasizes that no one person or group is solely responsible for scientific advances. The military organization is likely to overemphasize its own contributions and to avoid any mention of the work of any other group. In a most flagrant case recently a contractor purchased a standard rocket motor, placed a wooden shell around it with wings and tail, and fired the rocket. The publicity release from the military agency had much talk of anti V-2 missiles and implied considerable progress toward a solution. Actually no real advance had been accomplished. Such incidents are bound to cause difficulty.

It is believed that these difficulties can be overcome if there is mutual understanding and a desire to find a solution. Some definite suggestions will now be given with greatest attention given to actions which should be taken by the Air Forces since this lecture is addressed to Air Force officers.

Suggested Action by Scientific Groups. - There is a tendency on the part of some scientific groups to adopt an extremely narrow point of view toward their own responsibilities to the nation, to take pride in the technical excellence of their accomplishments but to take no responsibility for the sociological effects of their activities. Since the scientific method requires the isolation of certain aspects of natural phenomena and the ignoring of other aspects considered non-essential to the particular problem, scientists have a tendency to live in ivory towers out of contact with the world of commerce, industry, and human affairs. Fortunately these isolationist tendencies are passing and it is to be expected that scientists will accept some responsibility for national defense. While scientists prefer to devote their energies to peaceful pursuits and to call attention to the contributions of science to human welfare, they can not safely ignore completely the possibility of future wars. Hence every scientist and scientific group must see that steps are taken to keep in touch with problems of warfare, distasteful as the task may be.

It is also suggested that scientists make a sincere effort to understand the responsibility of our military forces and resolve to offer constructive rather than destructive criticism. As stated before the problem of securing cooperation between science and the Air Forces in peace time is an extremely difficult problem and requires for its solution constructive thinking on the part of all concerned. Scientists should be willing to take part in the education of military personnel, to serve as consultants and members of advisory committees, and to give a certain fraction of their scientific effort to military problems. First hand contacts make for the desired mutual understanding or high light conditions in scientific institutions and in the Air Forces which require correction. The building of the necessary partnership requires effort on the part of both groups and is not a one-sided affair.

Suggested Action by the Air Forces. - The steps which should be taken by the Air Forces to foster cooperation between science and the Air Forces were studied at considerable length by the Scientific Advisory Group to the Commanding General AAF and the following suggestions result largely from the work of that group.

The security problem can be solved by two steps:-

1. Adopt the point of view of the scientists toward fundamental scientific data even in such fields as supersonic aerodynamics, terminal ballistics, jet propulsion. All such data not referring to specific

military weapons or their design should be unclassified and military as well as civilian personnel should not only be permitted but encouraged to take part in the discussion of such matters at society meetings and publication of individual scientific contributions in technical journals.

2. Adopt the point of view of the military toward design studies of military weapons and the application of science to military problems. However, take steps to bring civilians into the partnership and establish a forum for discussion. The idea of compartmentalizing information on technical developments is entirely wrong and limits the rate of progress. Such security measures should be limited to operational planning. The specific measures suggested are the establishment of libraries of classified material in various technical fields available to properly cleared civilian scientists, the establishment of a scientific society with cleared civilian and military members holding classified meetings and publishing a classified journal.

The Air Forces should support direct research contracts between the Air Forces and scientific institutions both for fundamental and for applied research projects. A type of contract and working relationship which enables freedom in the methods used and recognizes the presence of unknown factors in research work should be developed. The procurement contract is definitely unsatisfactory. Provision should be made for statement of goals in general terms and for reasonable continuity of effort. Air Force personnel must learn the difference between a research problem and a development problem.

The Air Forces should exchange personnel with civilian scientific institutions. The Air Force personnel should not be assigned as reporters or as liaison or as supervisory officials but merely for the purpose of learning. They should be assigned for extended periods and preferably take part in the actual scientific work. Similarly arrangements should be made for civilian personnel to work in service laboratories and at service proving grounds and test stations.

The Air Forces at all levels should make use of civilian scientific consultants. They should be admitted as partners in the formulation of scientific policy and brought into contact with current problems. They should not be regarded as prophets of the future but as persons whose knowledge and experience should be utilized both in current problems and in planning for the future.

The Air Forces should give consideration to the formulation of cooperative laboratories in which the Air Forces would handle administrative, financial, and managerial questions and the staff members of the civilian agency would supply scientific direction. In this way a high level of leadership could be obtained which might not be reached in an institution in which the scientists were employees of the Air Forces.

Finally the Air Forces should undertake the establishment of a scientific reserve built up of scientists who have been associated by exchange with civilian institutions or otherwise with the technical problems of the Air Forces.

To sum up, science must be accepted as a real partner not as a hired hand to develop and operate gadgets.

Cooperation between Industry and the Air Forces

In the application of science to the development of weapons we must consider not only scientists and scientific organizations devoted to pure and applied research but also those agencies engaged in the development and manufacture of military equipment which make possible the wide application of science in providing the physical tools used by the Air Forces. We turn our attention now to cooperation between industry and the Air Forces.

Goal. - The goal is here the same as before, to bring industry into the partnership, to create a mutual understanding between industry and the Air Forces so that each is conscious of the other's problems, and to interest industry in Air Force development problems.

Industry has in general been primarily interested in production and has been unwilling to devote the efforts of its leading scientists and engineers to development problems. Profits have been a necessity for continued existence in a highly competitive world and profits are not usually to be found in the development of weapons. But industry also has a patriotic duty in peace as well as in war to devote some of its energy to national security and some method must be found to make this effort not only a matter of duty reluctantly undertaken but also a stimulating and challenging experience to be solicited.

Principles. - In this area also certain principles may be stated which have found general agreement. These are as follows:

1. Many military developments have no peacetime application and hence there is no commercial incentive for industry to undertake them.

> Even a casual acquaintance with the development of rifles, cannons, tanks, high explosives, etc., shows that not only is there an absence of the usual incentives to develop these weapons, but there is actually a stigma attached to these industries in

peace time. Their leaders are often accused of being war mongers and of soliciting business from our future enemies. Aeronautical developments have been along more fortunate lines because of the extensive use of aircraft in civil aviation. However the coming of supersonic speeds and pilotless aircraft is widening the gap between civil and military aircraft and some at least of the types of air weapons have no counterpart in civil aviation. Hence the same problems may be expected to arise as are present in ordnance development.

2. Industry should have a development as well as the production function.

The present relative role of the military agencies and industry in the development of new weapons and methods of warfare varies with the different types of weapons. Experience teaches that a partnership gives the best overall result and that each partner must take part in the development process. Manufacturing organizations without development groups within them are inflexible and tend to oppose the progressive improvement of equipment. On the other hand the experience of any manufacturing organization is too limited in the problems of the Air Forces to permit entrusting them with complete responsibility for development. The use of both groups, military and industrial, brings to bear a more varied knowledge and diverse skills as well as a greater number of persons. Furthermore and perhaps most important, the assignment of a share in the creative development of new things is the best method known of enlisting and maintaining interest. A further consideration is that the competitive element in private industry in the development of new products brings out the best specific designs.

3. The Air Forces must have the ultimate responsibility for evaluation of the final results.

Since the Air Forces are accountable for national security, they must be charged with the ultimate responsibility for evaluation of new methods and equipment. In this evaluation they may and should seek advice and utilize scientists and scientific methods, but the responsibility can not be shared with industry or with civilian scientific organizations.

4. Because of the time required to place newly developed equipment into large scale manufacture and to train personnel in its use, there must be in peace time the closest cooperation and consideration of the views and experiences of both groups as to industrial preparedness.

It is essential to give some thought always to the procedures and methods for making new equipment available to the Air Forces in time of need. Advances in scientific knowledge are constantly making existing equipment obsolescent or obsolete and therefore the degree of national security rapidly declines when reliance is placed on large quantities of existing equipment rather than on quality. The Ordnance Service has had a somewhat longer experience in cultivating close industry-Ordnance relations and this experience may be worth study by the Air Forces.

Difficulties. - The potential difficulties in Air Forces-industry cooperation appear to me to lie in the questions of profits, patent policy, proprietary information, and means of expanding production in time of need.

The question of the profits to be permitted to industry for development work is a matter of public policy just as is the question of profits on the manufacture of military equipment. There are wide differences of opinion which need not concern us in our present discussion. It is desirable that the Air Forces and industry come to some mutual agreement as to a policy to be recommended to the nation to remove this subject as a possible obstacle to cooperation. As will be discussed later one forward step would be to lessen the risk of development contracts to be no greater than that for production contracts. In that case, speaking as an individual citizen, I believe that agreement could be reached on some definite profit allowance in peacetime with a lower or perhaps zero rate in war time.

The second source of difficulty is that of patent policy. As is well known there are wide differences of opinion as to the patent privileges which should be retained by an industrial group conducting development projects under government contract. The difficulty arises from the very nature of the patent structure in most modern scientific developments. The art rests on the work of large numbers of people and most individual patents are of limited utility unless a great many other patents are also available for use. Industry itself has found it necessary to work out cross-licensing agreements. When industry takes on a development project, it utilizes all of its existing knowledge of the art including many patents already held. The first question is then as to the availability of these patents to the government; the second is as to the availability of these and other patents taken not during the development project to other contractors for the government; and the third is as to the rights to the commercial use of the patents taken out during the development project for non-military purposes. Here as in the case of profits it is desirable but perhaps impossible to arrive at a general policy acceptable to industry, the Air Forces, and the general public.

The third possible difficulty is another version of the second, namely, the extent of use of technical data and of other so-called proprietary information not protected by patents. It is often of value to the Air Forces to disseminate technical data in new fields as widely as possible to its contractors. This is now the case in jet propulsion, guided missiles, and supersonic aerodynamics. Likewise in war time it is often desirable to take a product completely developed by one company and turn over all drawings, plans, and technical data to another company for obtaining increased production. With few exceptions, industry cooperated extremely well during the war and is now cooperating in the dissemination of technical information in the newer technical fields. However this matter is obviously a possible point of difficulty and a mutually satisfactory policy should be agreed upon.

The final point of possible difficulty relates to the extent of use of new and inexperienced contractors. It is quite obvious that development should proceed most rapidly and arrive at a better result in the hands of industrial organizations with well-qualified personnel, good facilities, and long experience. On the other hand the production facilities of these organizations may be insufficient to produce the quantity required in an emergency. Shall other new contractors be given development contracts largely for educational purposes? What use if any should be made of relatively small organizations? Neither the policy of supporting a "chosen instrument" in peace time or of educating competing groups fully satisfies the demands of high-quality technical development and good industrial preparedness; the first may lead to single-track development and stagnation, the other to inefficient use of resources.

Suggested Action by Industry. - In peace time industrial as well as scientific organizations prefer to turn their attention to the development and manufacture of equipment and products to promote human welfare. Nevertheless industry also has a patriotic duty to devote a certain percent of its effort to the problem of national security. The action suggested by industry is the formal recognition of this responsibility, the establishment of small development groups and the acceptance of development contracts. Perhaps industry advisory committees could be set up to work out jointly with the Air Forces the general policies which should govern such work.

Suggested Action by the Air Forces. - In order to secure the cooperation of industry it is essential that the Air Forces clearly distinguish development projects from procurement contracts. The types of contract, nature of supervision, and method of evaluating the results obtained are so different that the two activities should be handled by different groups. Specifically, practically every scientist and engineer who will express an opinion recommends the removal of procurement activities from Wright Field and the assignment of technically trained personnel to handle development contracts.

In many of the modern developments test facilities are required of a magnitude too large to be furnished to each contractor at government expense. In such cases the large facilities must be provided by the government at a single location but to accomplish their purpose they must be available for use by the engineers of the contractor. While the government must control the assignment of priorities and determine the length of time the facilities are to be used on a particular development project, the contractors engineers should control the actual use of the time. If the same facilities are to be used by the Air Forces for evaluation tests, these tests should be made at a later date by Air Forces engineers when the industrial group is ready for such tests.

When the evaluation is completed of equipment for which there is no commercial use and it is determined that there is a tactical or strategic requirement for the equipment in time of war, the Air Forces should support tooling and pilot production of the new equipment, bearing the full cost.

The Air Forces should in cooperation with industry work out an orderly plan for the use of both development and production facilities in peace time. These plans should be flexible and adapted to various levels of expenditure. It is the responsibility of the Air Forces to determine and recommend that level of expenditure deemed necessary to retain leadership in technical progress.

The Air Forces should invite the cooperation of the commercial air lines and privately operated air transport facilities for trials of navigation systems, operating procedures, handling of mail, passengers, and freight. In this way an increased body of operating experience will be obtained and a reservoir of trained personnel suitable for air transport operations will be maintained.

By these and other steps which will occur to you an effective team will be created to pool the efforts of pure scientists, applied scientists, engineers, production experts, industrial and military planners, and Air Forces operating personnel to maintain the United States strong and safe against aggression.

Effective Use of Scientific and Technical Facilities Within the Air Forces

We now turn our attention more specifically to science within the Air Forces organization itself and the steps to be taken to improve the utilization of science and scientific methods by Air Forces personnel. The physical tools for the scientific and technical development and evaluation of new weapons and new tactics are laboratories, test stations, and proving grounds. The Air Forces must have such facilities and use them effectively.

The Air Forces does in fact operate laboratories, test stations, and proving grounds and many of its facilities are outstanding. If you are not already acquainted with them, you will presumably have the opportunity to become so during this course of study. The Air Forces have been very progressive in planning new facilities and have been reasonably successful in securing funds for first rate apparatus and equipment. The present facilities are, however, inadequate in the light of the more recent scientific developments.

In the first place the present facilities are largely confined to the development of the physical weapons such as aircraft, guns, electronic equipment, etc, and insufficient attention is given to the human operators both in their capacity as biological mechanisms and as intelligent beings seeking to accomplish certain end results. The aeromedical laboratory has made a fine start in its studies of the effect of environment on the performance of human beings. However, the resources of the other biological sciences such as psychology should also be brought to bear on the problems of aerial warfare. Not only training aids and training methods but also the relations between mechanical design of devices and their effective use by human being require scientific study. Likewise the methods of operational analysis should be further developed. All of these developments require physical facilities in the form of laboratories, computing machines, measuring instruments, etc. It is probable that a more intensive study of the field would reveal other areas not covered by present facilities.

In the second place the modern scientific developments have shown the necessity of much closer integration of the contributions of the specialist laboratories. Even in aircraft design it is now recognized that the armament and electronic equipment can not be regarded as accessories to be installed on almost any aircraft after completion. Just as the engine and airframe have always had to be designed together as a unit, so now the complete military weapon must be designed and developed as one integrated whole. The coming of guided missiles has further emphasized this need, for in these weapons there is no human intelligence or skill to give some compensation for poor design, It is no longer possible to develop separately engine, air frame, electronic equipment, armament and assemble them into a satisfactory weapon. The whole purpose of the weapon must be studied and the conflicts in design requirements of the components resolved in such a way as to best accomplish the purpose.

The German experience indicates the effectiveness of development centers like the one at Peenemunde for such purposes. Development centers are needed to carry on such integrated development programs in three fields, i.e. supersonic and pilotless aircraft, nuclear aircraft, and aircraft operations. The first is self-explanatory, the second deals with the application of nuclear energy to aircraft propulsion, while the third provides for the study of traffic control at military air fields, fighter control, radar and television applications to navigation and other operations, and similar matters. I understand that the Air Forces are taking steps to meet these needs although probably not in the exact form suggested.

Development centers of this type are likely to involve test installations of large size and cost and requiring large amounts of power. Such large facilities present many special problems. Because of the size, cost, and power requirements, the nation can not support more than one such facility of any given type. However there are many groups wishing to use large facilities, including other governmental agencies, military and civilian, manufacturers holding government contracts, and other civilian groups. Some method of administration must be devised to insure that all qualified groups can join in using the facility for the best interests of the nation.

Laboratories, test stations, and proving grounds are in themselves only physical tools to be used by men. The effective use of the facilities depends entirely on the caliber of the men using them. It is a common mistake of laymen to judge the scientific competence of a laboratory by the number, variety, and appearance of special pieces of apparatus. Some of the most impressive laboratories turn out poor scientific work and many of the major contributions to science have come from poorly equipped and poorly supported laboratories. Of course good tools help in producing good results. The point to be made is that the effective use of scientific and technical facilities demands the best possible personnel, and that good facilities are not a substitute for able scientists. We are thus led to consider the scientific and technical training of AAF personnel.

Scientific and Technical Training of Air Forces Personnel

The recruitment and training of scientific personnel to staff the service laboratories, test stations, and proving grounds is but one aspect of the broad problem of the scientific and technical training of Air Forces personnel. Well qualified and able scientists are needed not only in the research and development activities but also on the staff and with the operating units. Moreover all personnel in positions of responsibility should be able to evaluate scientific facts with sound judgment and with some vision of future developments:

The training need is thus a dual one. We can not expect that every member of the Air Forces will be trained as a specialist in all fields of science and engineering, but specialists in all fields are needed. Each member must attain a broad knowledge of scientific and technical matters and some must be leaders in highly specialized fields. Without such leaders the Air Forces are doomed to mediocrity in scientific and technical matters with a personnel who are jacks of all trades and masters of none. The program of education and training in science must provide both types of training. The needs for highly specific and specialized training of technical leaders are as great as those for similar specialized training of tactical leaders.

The fact that leadership can be maintained only by an organization containing specialists in various fields has many implications as to personnel policies which will be discussed in further detail somewhat later. It should be mentioned here however that specialists can have expert knowledge in only one or a few related fields and hence their knowledge is useless unless they are assigned to duties in those fields.

It is desirable that all scientific and technical personnel including the specialists have some broad training in tactical matters and that many become aircraft pilots. I do not believe that this training can or should be carried to the point where the man is regarded interchangeably as expert scientist, expert tactician, and expert pilot. Neither do I believe that the holding of a pilot's rating should be made a prerequisite to the holding of positions whose principal duties are scientific and technical. There is no direct relation between ability as a pilot and ability as a scientist or engineer. Some pilots are also scientists, and some scientists are pilots but the number of persons with combined skills is small. The results of entrusting technical decisions to technically unqualified persons are inefficiency, waste, and delay.

It is desirable that all Air Forces personnel have some actual experience in doing scientific work, preferably coordinated theoretical and experimental work, early in their career under the guidance of qualified scientists. The best way of learning is by doing. This experience may be nothing more than the usual laboratory course in a civilian school, or it may be obtained in one of the service laboratories. The assignment of personnel to do actual experimental or design work at a service laboratory should be as essential an element in the broad training of Air Forces leaders as assignment for duty with a field operating group. No person should try to direct a development laboratory or any important development project who has not had actual experience in development work. A constant source of difficulty in military development is the project officer without actual experience in laboratory or shop.

The Air Forces personnel consists of military and civilian groups, both of whom need to be trained in science. By tradition the military group is the more mobile and the civilian group more fixed in location and type of work. It is therefore to be expected that the more highly specialized scientists would be found in civilian positions. The constant change in assignment of military personnel from one type of activity to another and the current policies as to promotion and advancement tend to discourage specialization. I think this situation is unfortunate for the Air Forces. It is to the advantage of the Air Forces to have its scientific facilities directed by military personnel but it is of much greater advantage to have them headed by able scientists and engineers. Some method must be found by means of which military personnel with scientific and technical background are given extended advanced training in science (not short courses) and assigned to the leading technical positions. The alternate solution, less desirable in my opinion, is to set up the AAF scientific facilities under civilian direction.

The AAF has a recruitment problem as well as a training problem in the filling of its scientific and technical positions. The biggest source is at present the large number of people with scientific background who are already in the Air Forces but whose scientific skills are not being utilized. Another feeder should be the graduating classes at various colleges, with special attention given to the ROTC groups.

The scientific training can be given by many methods and at many places. The regular Army officer will ordinarily have received scientific training at West Point, the civilian scientist and reserve officer at a civilian college, all prior to joining the Air Forces. After entering the Air Forces, formal training may be given in a service school such as the Air Forces Institute of Technology at Wright Field or in a civilian university. Ordinarily it is most effective to give advanced training at a civilian university and arrangements are now in force to send selected Air Forces officers for graduate study at various universities. Similar arrangements should be made for civilian employees of the Air Forces. In both cases, definite procedures should be established to assign persons receiving such training to technical duties and to retain them in such positions.

In all scientific work it is necessary to keep up to date with technical advances. For this purpose the individual should be encouraged to read widely and to associate himself with other scientists in technical societies. As previously mentioned, the classified nature of much of the scientific work in the Air Forces suggests the establishment of a new technical society or institute of military sciences with cleared membership, classified meetings, and classified publications.

Another method of continued training already mentioned is the exchange of personnel with other scientific laboratories. The Air Forces personnel should stay a sufficient length of time to take part in scientific work and make some contribution to it.

Formal repeat and refresher courses, especially in new fields of science and technology and lectures by civilian and military scientists are other methods of training personnel. Courses of short duration of the highly specific type are of great value to technicians who will be called upon to service and maintain new weapons. It is however not practical to give adequate professional training by such short courses. Opportunities should be provided for periodic assignment of technical personnel to civilian universities for periods up to one year for additional training and for refresher courses. The curriculum for such courses should be worked out jointly by the Air Forces and the universities.

Induction of Scientific Ideas in Command and Staff.

Major advances have already been made at the command and staff levels in providing for the introduction of scientific ideas. General H. H. Arnold had the foresight to originate the development of a long-range research program and created the Scientific Advisory Group under the leadership of Professor Th. von Karman to advise him. General Spaatz has likewise established a Scientific Advisory Board with Prof. von Karman as director to advise him on scientific matters and especially to study the long-range scientific needs of the Air Forces. General LeMay as Deputy Chief of Air Staff for Research and Development is directly responsible to the Commanding General for coordinating the research and development activities of the Air Forces. These actions are evidence of the sincere interest of the top management of the Air Forces in the fuller exploitation of scientific knowledge and scientific developments.

In most large business enterprises it has been found desirable to separate the research and development function from manufacturing and other operations. Many scientists sincerely believe that the Air Forces should separate research and development from procurement, making the Deputy Chief of Air Staff for Research and Development directly responsible for carrying out the research and development activities. They believe that the rigid linking of research and development to the present type of military requirements handicaps the development of novel weapons. They believe that the scientists responsible for research and development should decide what developments are worth investigation. If the military requirements cover merely an improved form of existing weapon, the procurement agency could probably obtain the desired article using the development facilities of industry. Those who oppose the separation of the two functions fear that the research and development effort will be diffused into impractical half-baked schemes without consideration of the real needs as seen by the operating groups. I think that the experience of the last war taught the value of contributions from free research and development groups and showed that such groups need not be unmindful of field conditions. Many of the most valuable new weapons had to be sold to the operating groups and the selling was often assisted by enemy use of similar devices.

If full use is to be made of scientific talent, scientific personnel must be introduced into all of the major divisions of the top administration of the Air Forces, not merely in the material groups. Perhaps the most urgent need is a complete overhauling of personnel policy to provide for the effective utilization of scientists. The theory that any intelligent officer can direct any organization, military, technical, or scientific is certainly obsolete as is the theory that any intelligent person can be adequately trained to do creative scientific work by accelerated short-term courses in technical subjects. Both in the military personnel administration and in the Civil Service Commission steps must be taken to place the selection, training, classification, promotion and assignment of scientific and technical personnel in the hands of men who have themselves had a scientific or technical background. Further the direction of scientific work must be placed on a par with general administration and command positions and should carry a military rank commensurate with the importance of the work. Scientific and technical personnel must be retained in the same assignment for a sufficient length of time to enable them to make substantial contributions. Promotion must be dependent on scientific and technical accomplishments to a greater degree than on mere seniority. Especially at the present time when there is a great shortage of scientists and engineers, the Air Forces should take every step possible to make full use of the talents of present personnel. There is a belief among civilian scientists that there are now within the Air Forces many scientists and engineers who are not assigned to technical work because of the application to them of general policies which affect all members of the Air Forces but which are particularly unsuitable for application to persons in whom there is a large investment of special training and experience.

A second need is for the more effective use of scientists in the intelligence activities of the Air Forces. It is not possible to train non-scientists to evaluate the significance of scientific and technical work. It has become essential to have scientists associated with our military attaches abroad to maintain contact with general scientific progress. It is desirable to send scientists of the Air Forces personnel, military and civilian, to international scientific congresses, and to send some scientists of the Air Forces to foreign educational institutions for study. Since scientific advances may be made anywhere in the world, it is only by such means that the Air Forces can keep in touch with scientific developments which have application to aerial warfare. A certain number of scientists and engineers are needed for the purpose of examining patents submitted and to keep in touch with domestic scientific groups. In the present time of shortage of technical personnel, the diversion of scientists from actual development work to liaison and intelligence activities should be kept to a minimum. Such duties would be suitable for short period assignments of research and development personnel.

A third need is for the more effective use of science in plans and operations and in particular the development of improved methods of operational analysis. This is a comparatively new field in which much pioneering work was done during the last war. Much remains to be done. There must be integrated planning by scientist and strategic and tactical planner for the evolution of methods of aerial warfare and of new weapons and their strategic use.

Conclusion.

In this lecture I have tried to bring out the opportunities, problems, and difficulties which confront military and scientific personnel in establishing that mutual understanding and confidence essential to the formulation of a working partnership. I fear that the recent spectacular exploitation of that scientific knowledge which was slowly and painfully accumulated over a number of years of peace by scientists of many nations has oversold science and led many persons to unwarrented expectations. Science is not a magic producer of miracles but a method or procedure of tackling problems which has led to many spectacular results. I hope that you may have received some understanding of the contributions to be expected from science and some incentive to further study.